EXHAUSTION

Air pollution levels over Europe under various future emission scenarios

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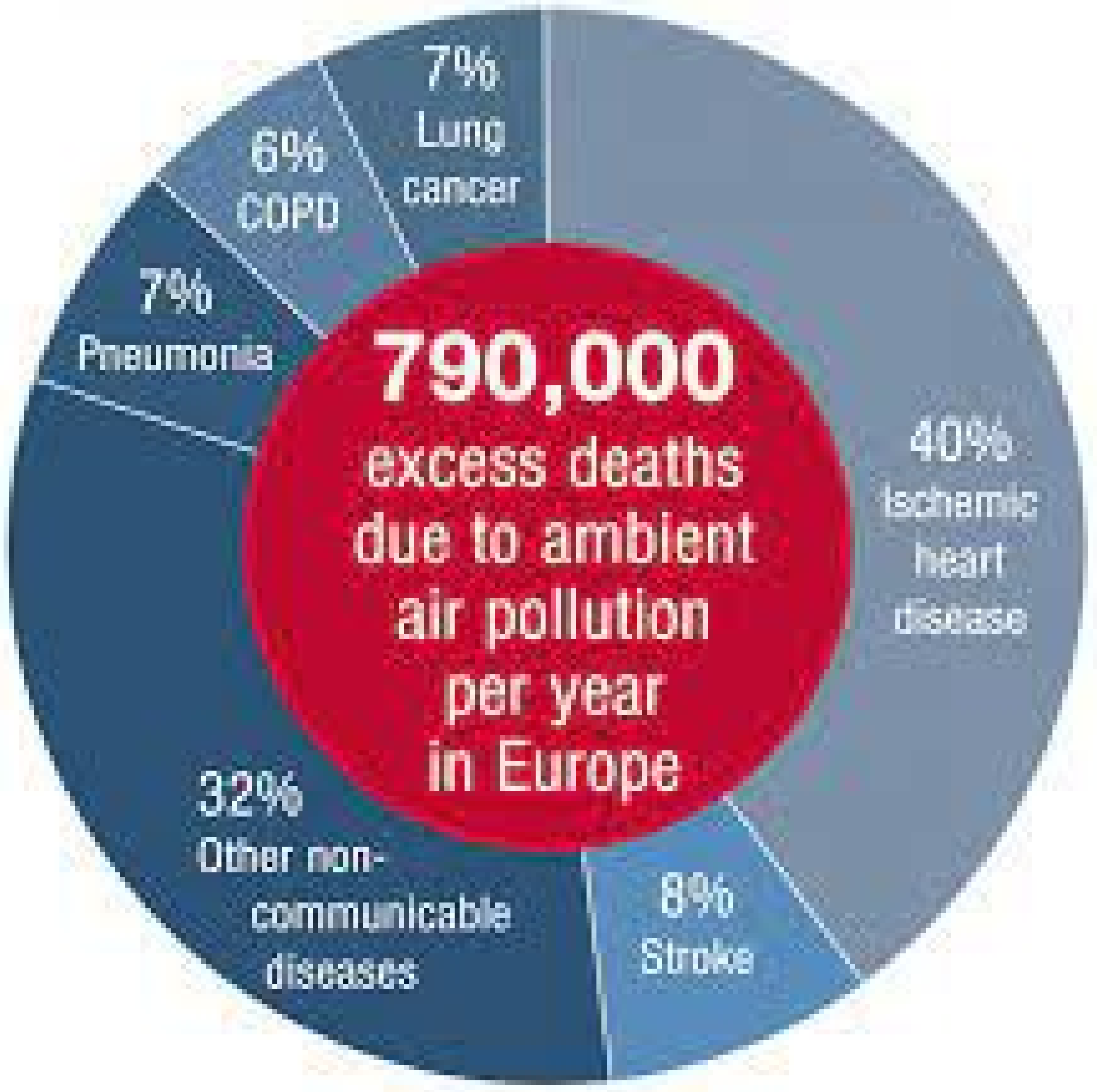
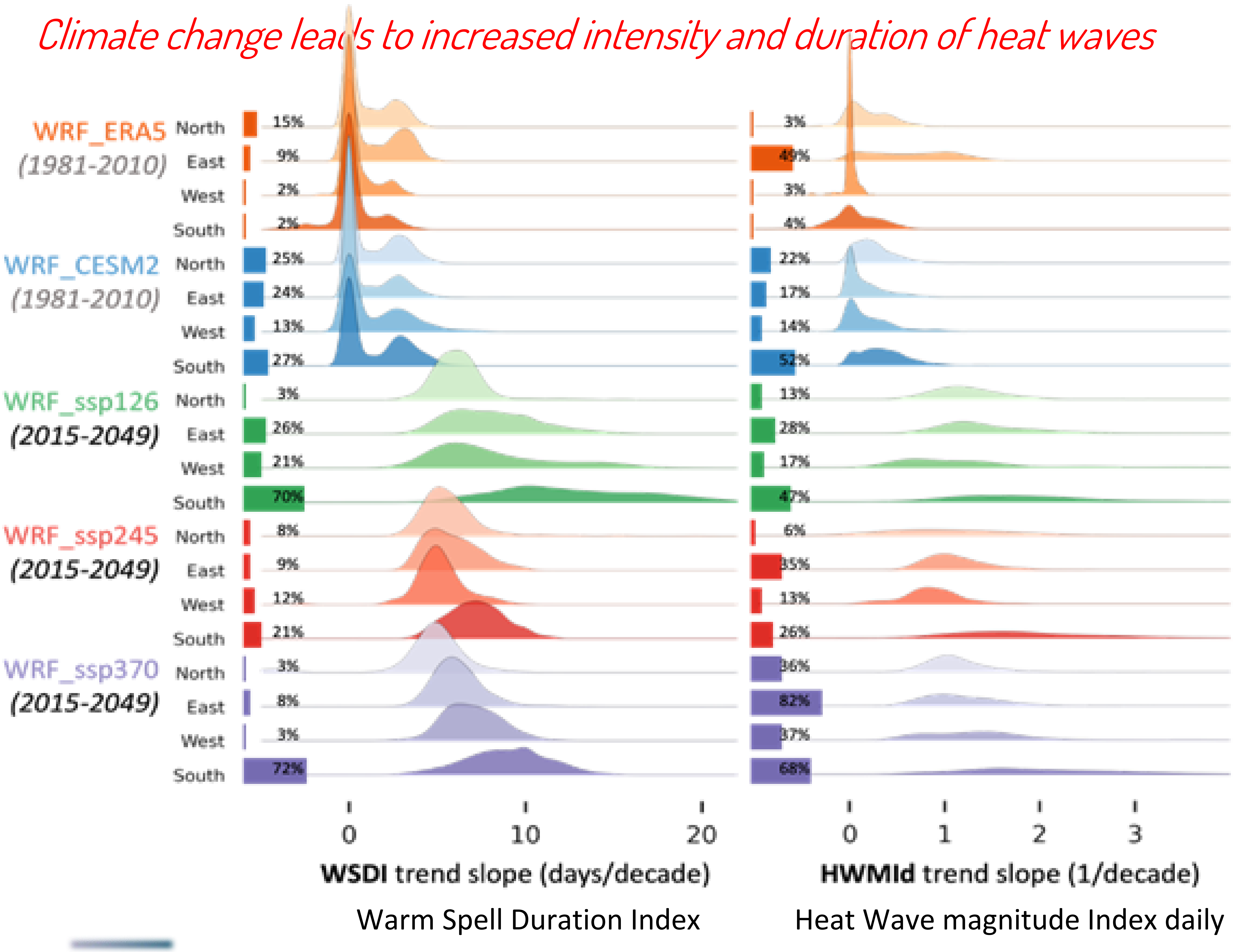
INTRODUCTION

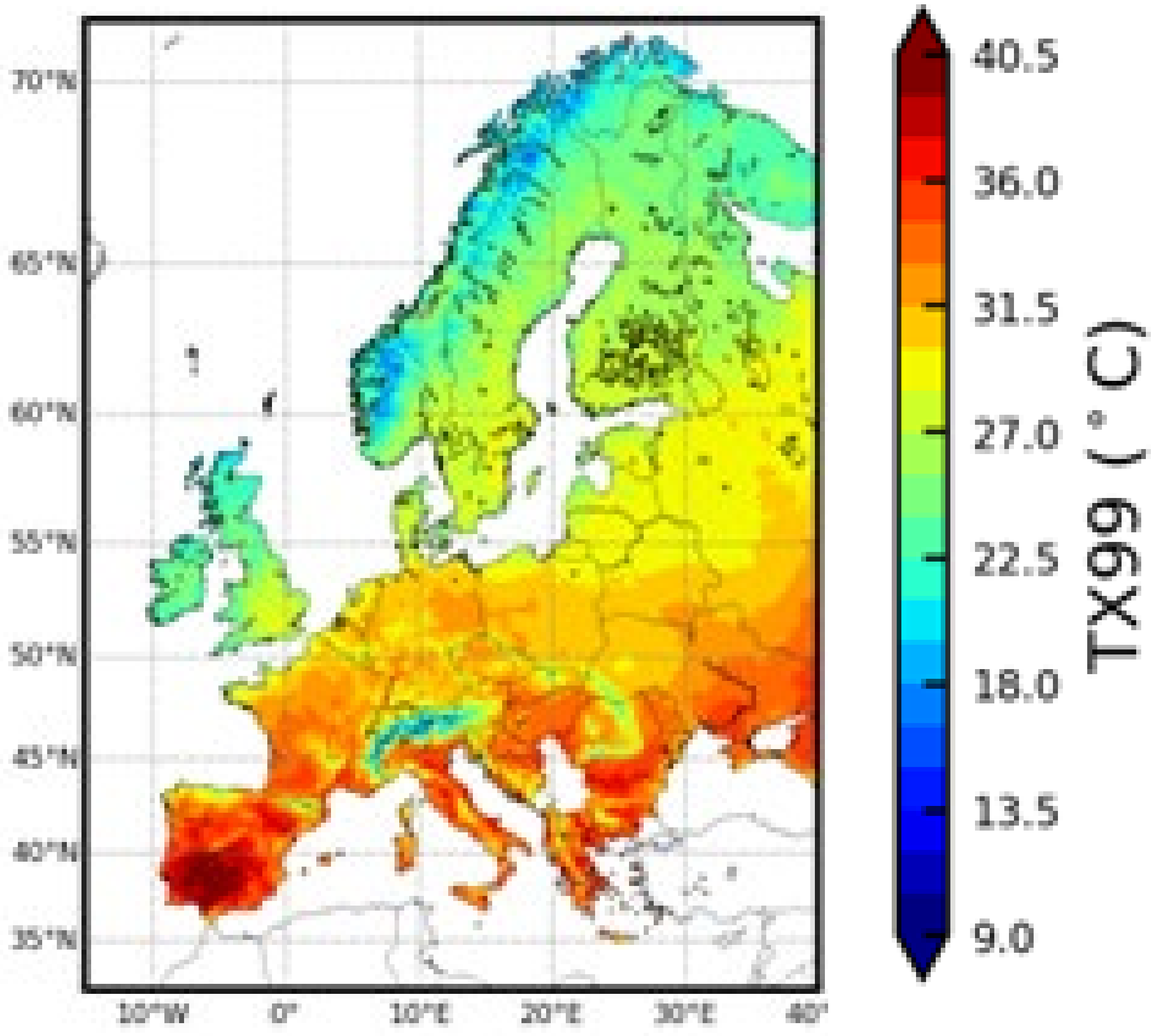
- Air pollution is today the environmental challenge associated with the highest mortality in Europe.
- Heat waves and extreme temperatures directly impact mortality and morbidity.
- *Reducing the rate of increasing cases of heart and lung diseases, or even avoiding them altogether with preventative measures, will substantially impact society by saving healthcare costs and improve quality-of-life through reduce suffering for many people.*



MOTIVATION – I

Climate change leads to increased intensity and duration of heat waves





- Heat waves are predicted to increase at even faster rates under even the most ambitious scenario.
- All regions across Europe are experiencing **increased** rates in temperature trends compared to the past
- **S**outhern Europe stands out as particularly vulnerable.

Ye et al., 2023, In prep.

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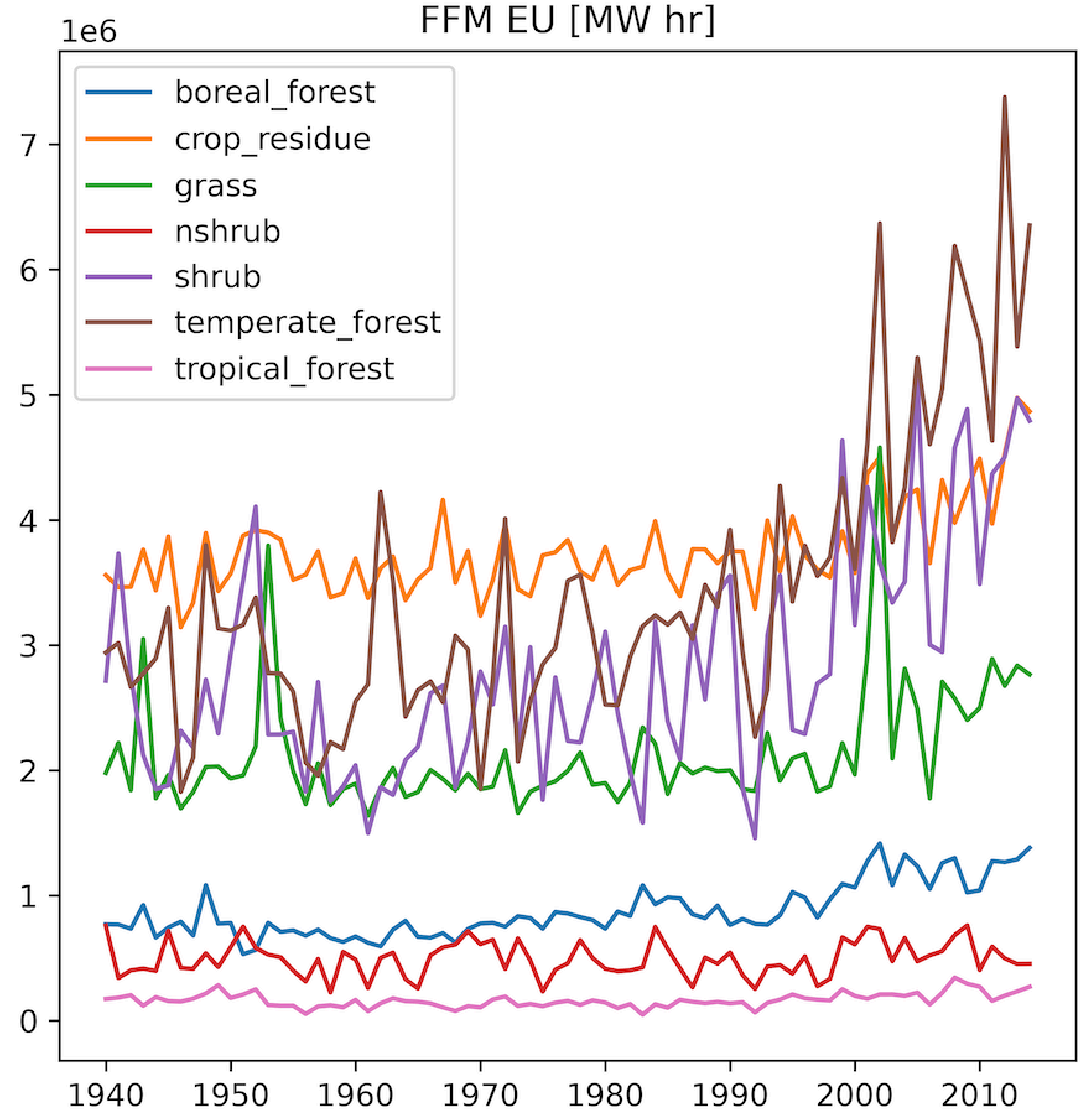
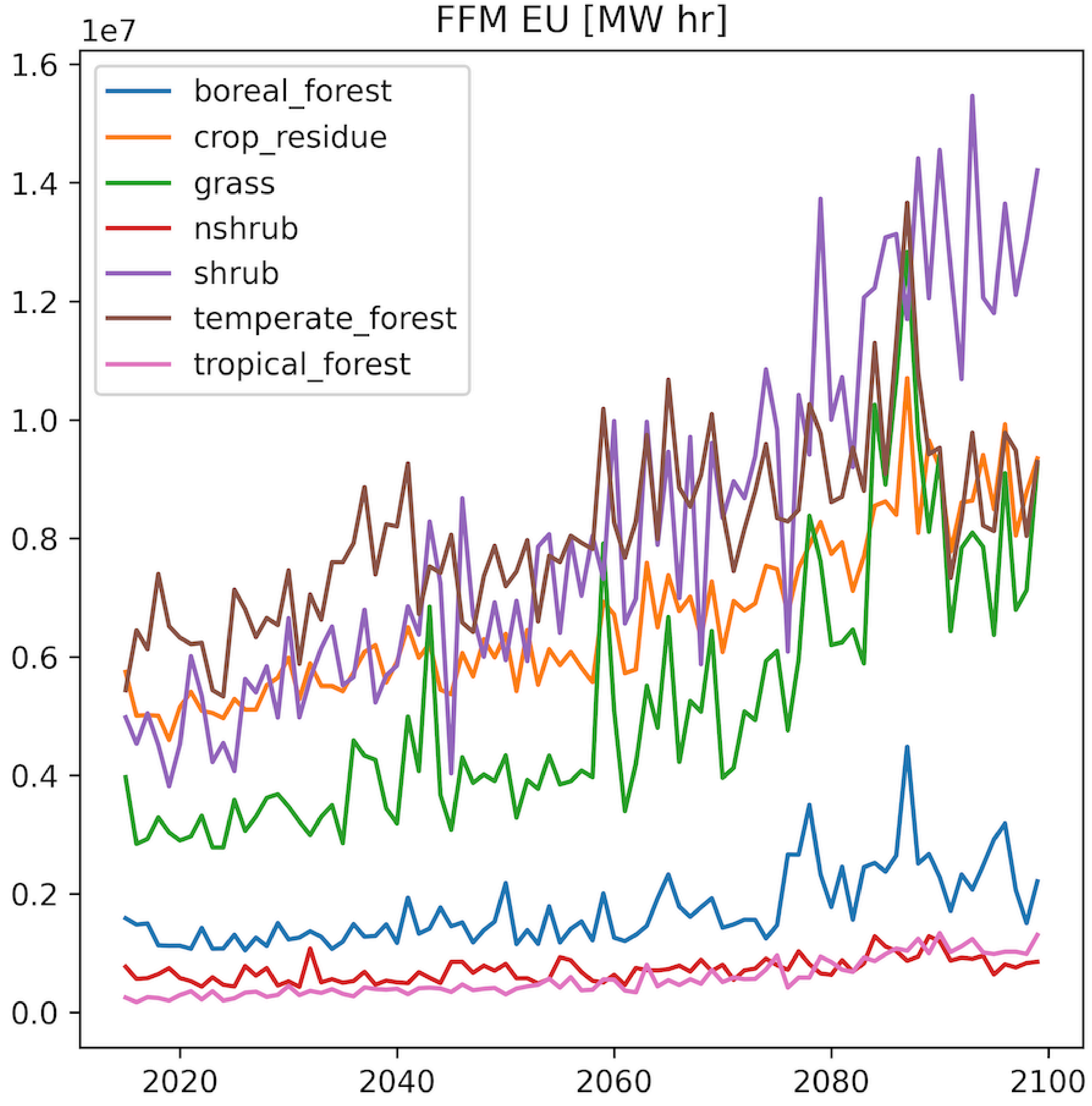
MOTIVATION – II

Droughts and heat waves are expected to lead to increased wildland fires, a source of air pollution

IS4FIRES CESM HIST



IS4FIRES CESM SSP3-7.0



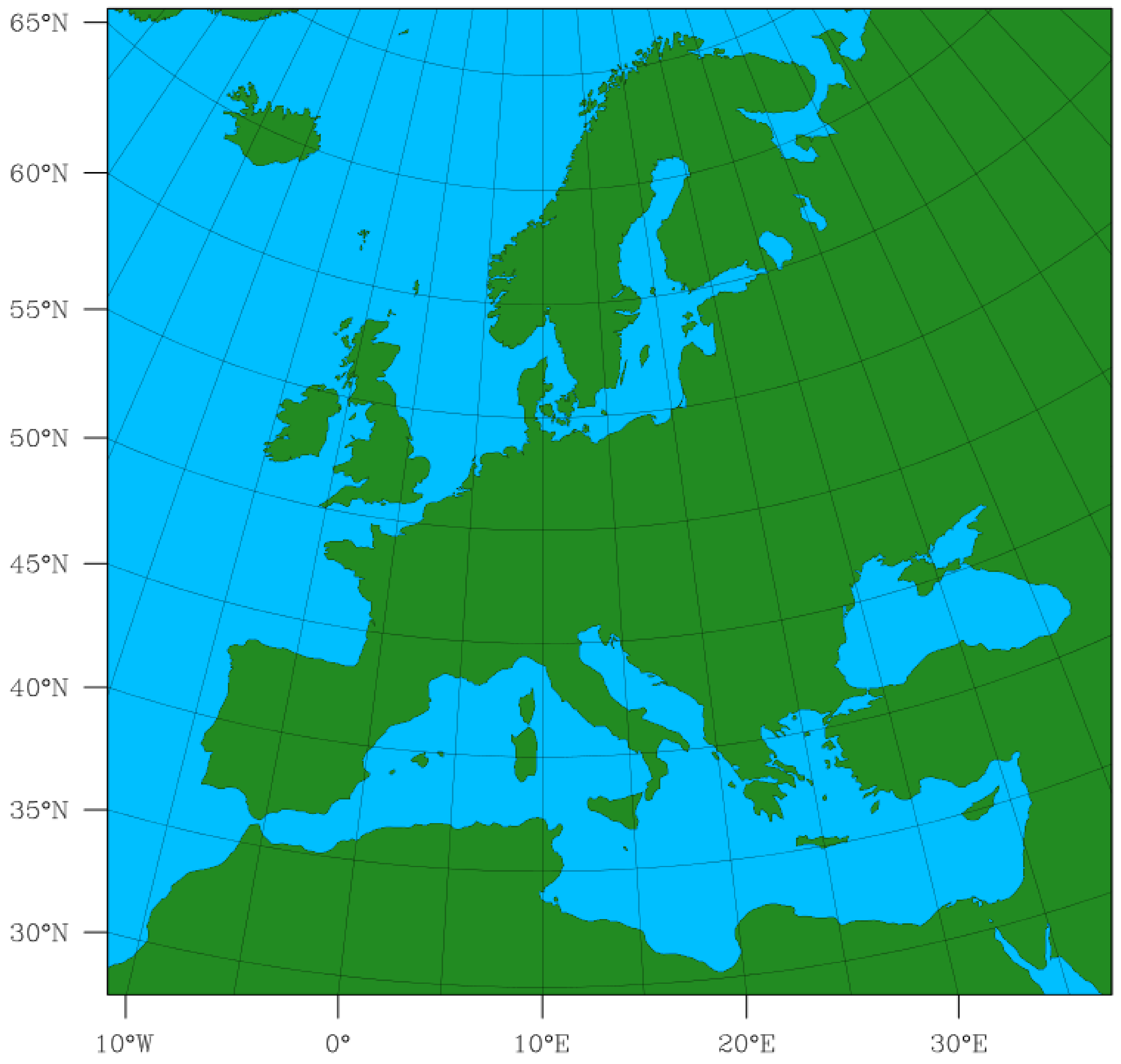
- **Large increases in grass, shrub, crop, and temperate forst fires in the future**
- **In particular after mid-century**
- **Increased air pollution episodes in downwind areas**

Sofiev et al., In Prep.

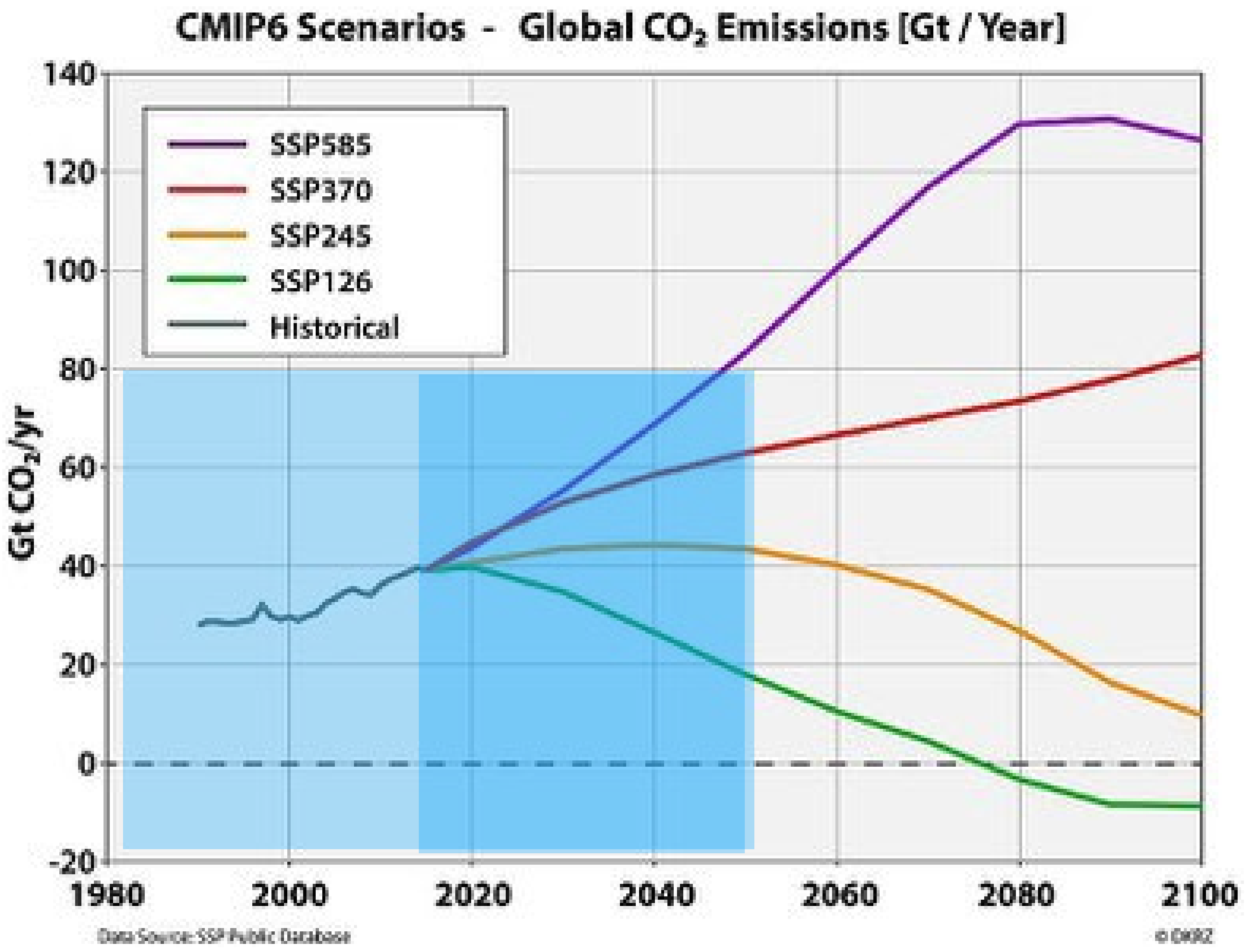
METHODOLOGY

- *A multi-model ensmeble of state of the art chemistry transport models to dynamically downscale climate and air pollution levels over Europe.*

  - Danish Eulerian Hemispheric Model (DEHM)
  - Integrated modeLling of Atmospheric coMposition (SILAM)
  - Weather Research and Forecasting model with Chemistry (WRF-Chem)

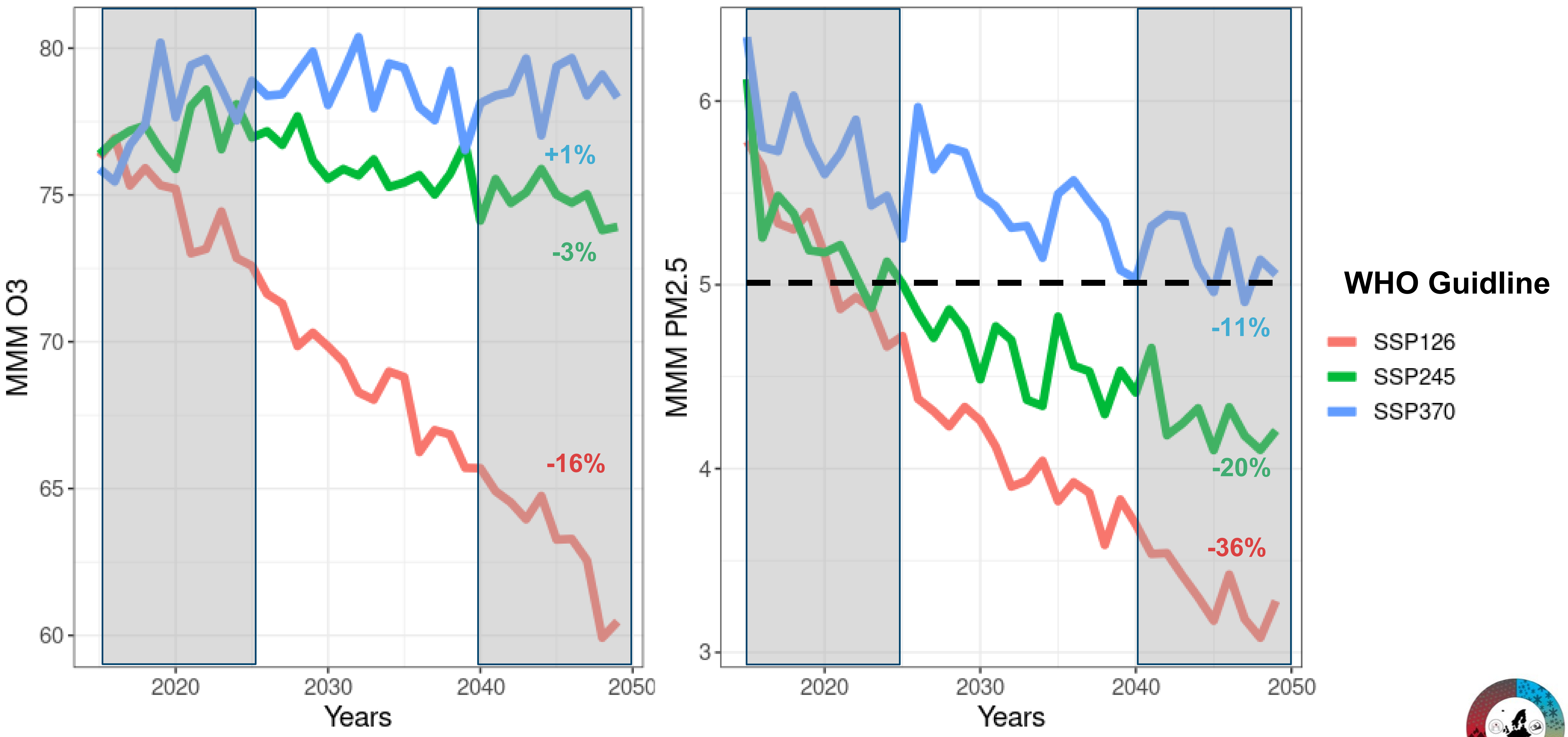


- 2015-2050 under 3 scenarios
- Coupled Model Intercomparison Project (CMIP6)



FUTURE SURFACE CONCENTARTIONS

%: Mean (2015-2024) vs Mean (2040-2049)



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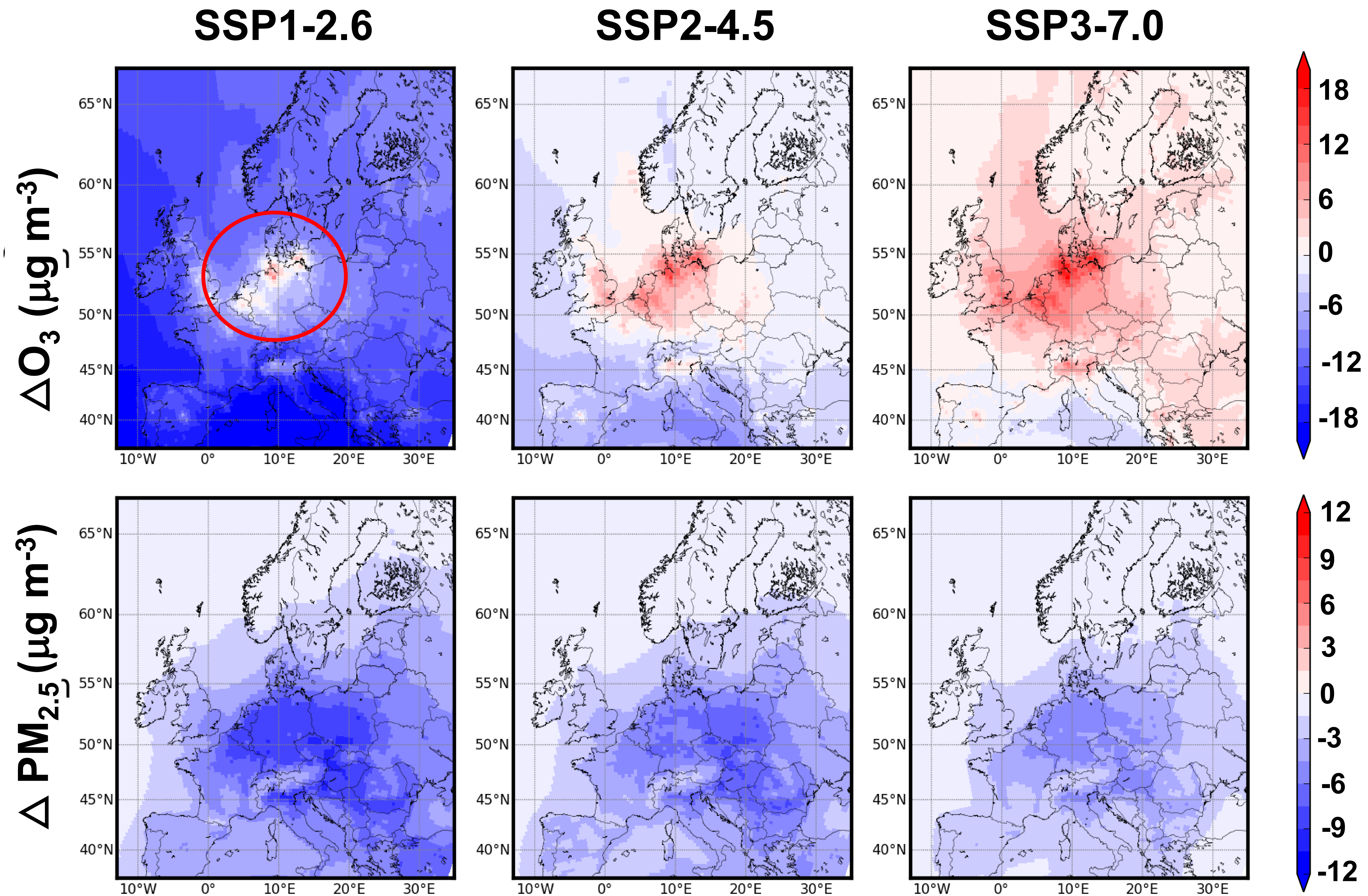
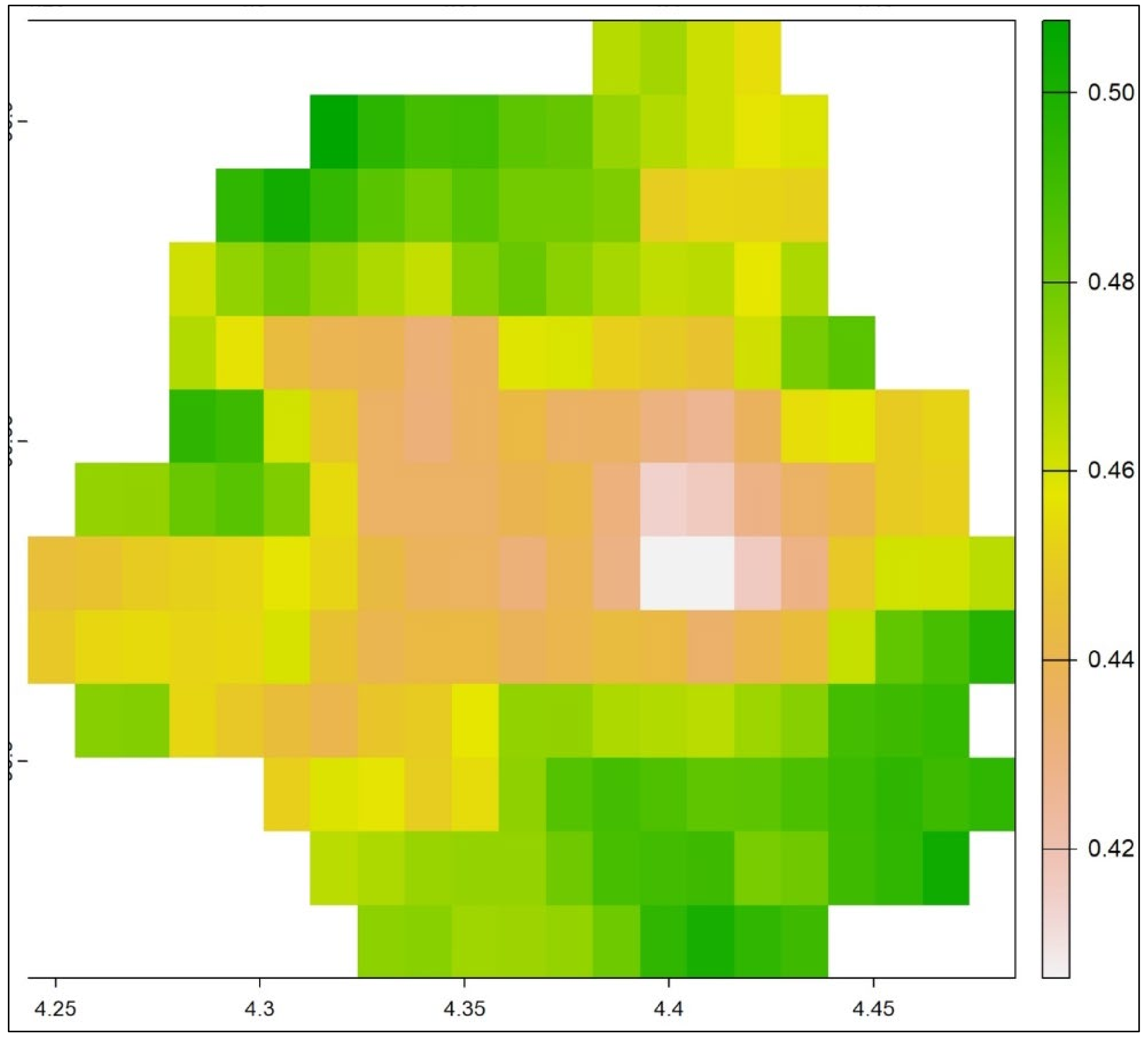


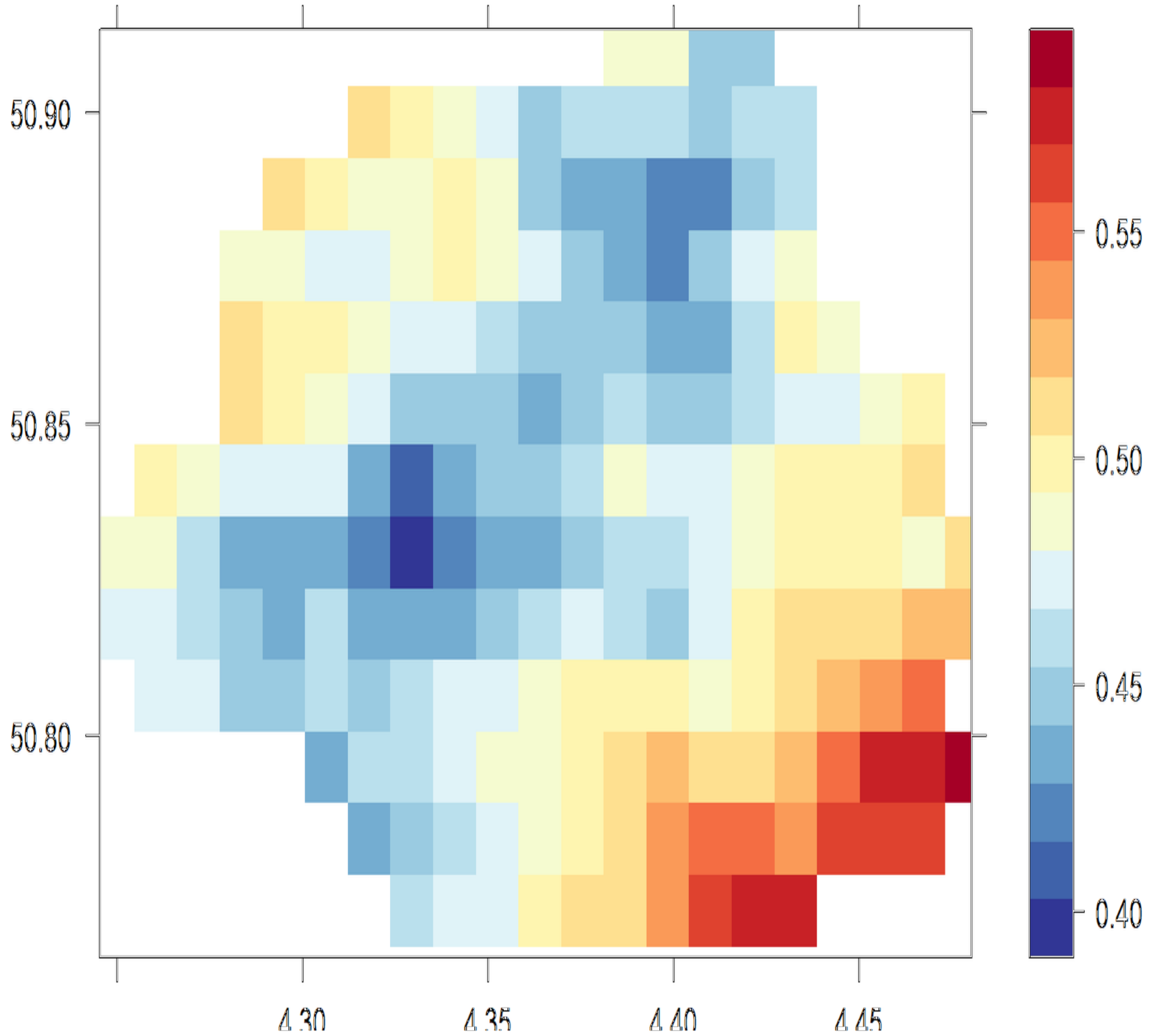
- Response in central Europe stands out
- Ambitios mitigation leads to reductions in both O_3 and $PM_{2.5}$ throughout Europe

STATISTICAL DOWNSCALING TOOL – BRUSSELS

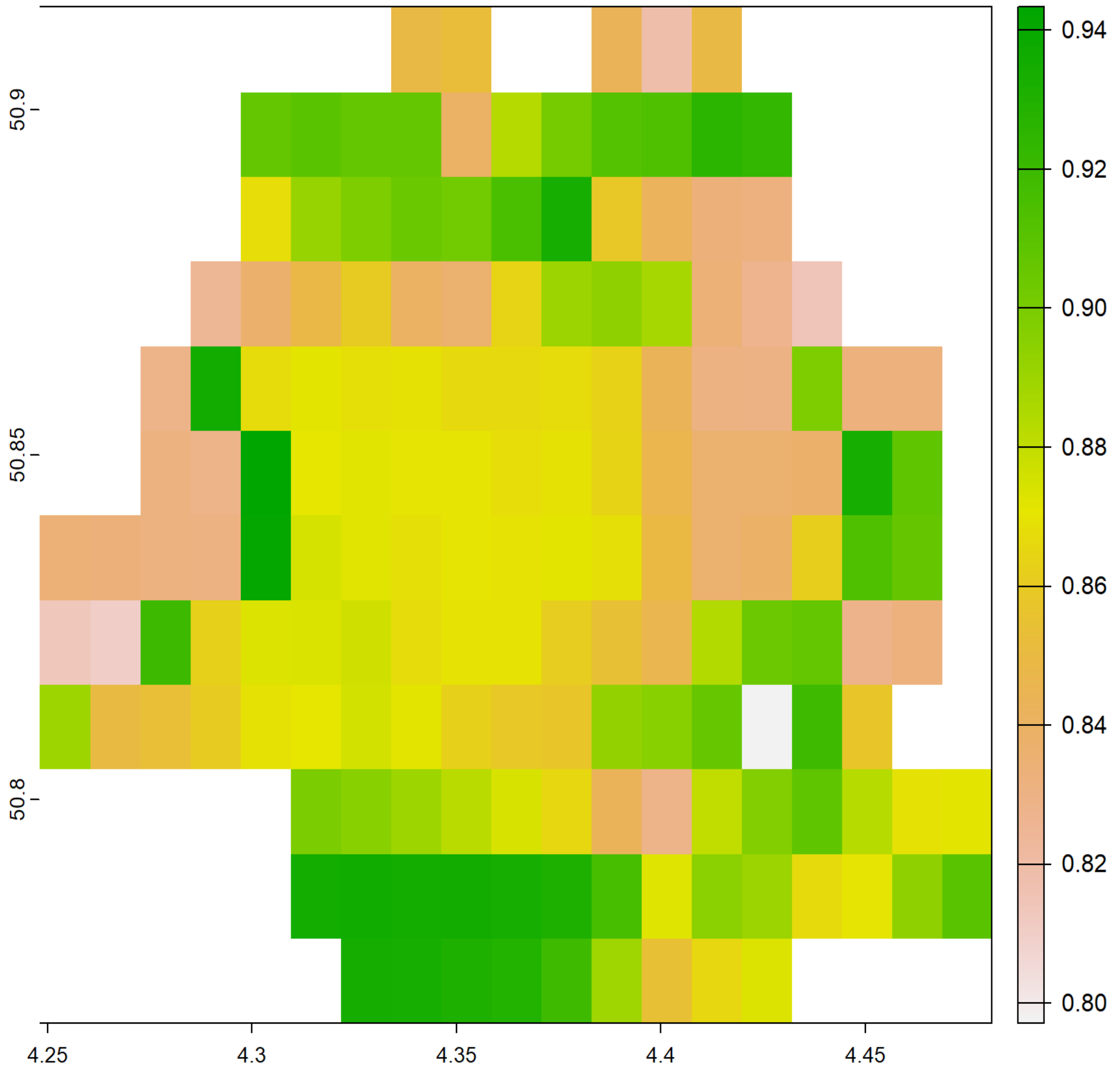
Correlation coefficients between observed and simulated surface temperatures



Daily mean temperature difference (℃) winter days (DJF 2015-2049) SSP1 RCP 2.6 vs. DJF 1980-2014



Correlation coefficients between observed and simulated annual $PM_{2.5}$



- Statistical downscaling from 30 km to 1 km spatial resolution using satellites and in-situ measurements

KEY MESSAGES

- Heat wave duration & intensity + wildland fires are expected to increase leading to *elevated air pollution levels*
- There is increasing temperatures in all cities but heat island effect depends on local conditions
- Over Europe, surface concentrations are *projected to decrease under all emission scenarios* (not O_3 SSP3-7.0) by up to 21% for O_3 and 43% for $PM_{2.5}$
- *Ambitous emission reductions* can take the air pollution $PM_{2.5}$ levels below the WHO recommendations on a regional level
- Multi-model enemsbles can provide *more reliable* results compared to single models & some indication of *uncertainty* (or model disagreements)

KEY RECOMMENDATIONS

- Regulation of health and climate relevant air pollutants, following the ambitious socioeconomic and emission pathways, are required immediately to improve the health of European citizens and go below WHO recommendations.

- Urban and land-use planning should be taken into account for heat adaptation and action plans.

- Observation networks with focus on health relevant air pollution should be extended to provide a data-driven evaluation of mitigation and adaptation strategies and predicted impacts.

THANK YOU

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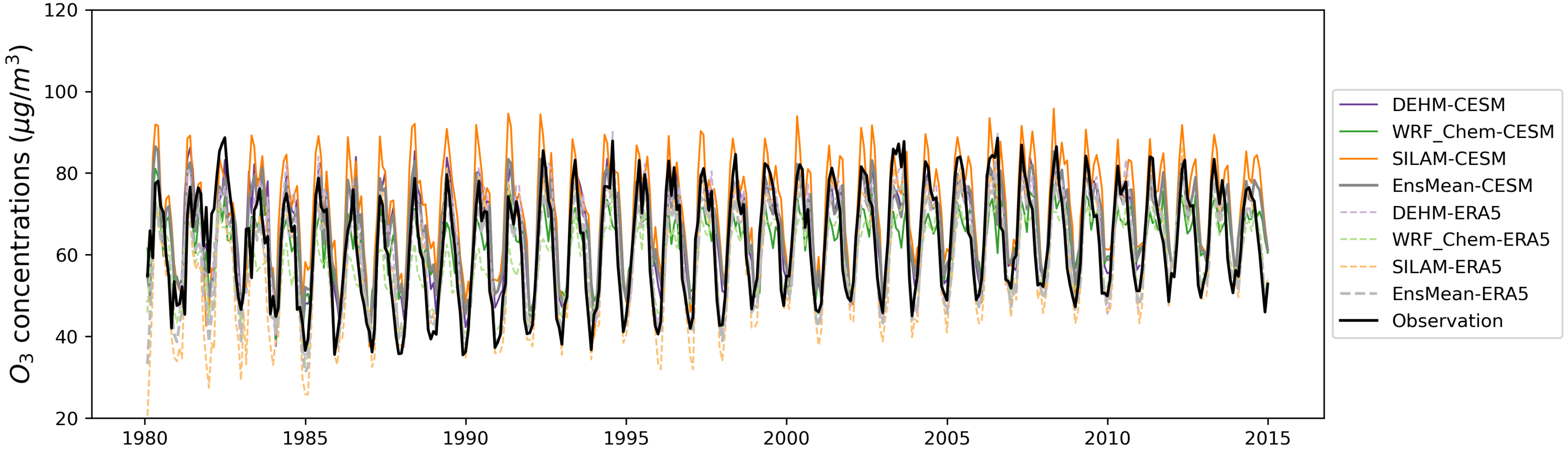
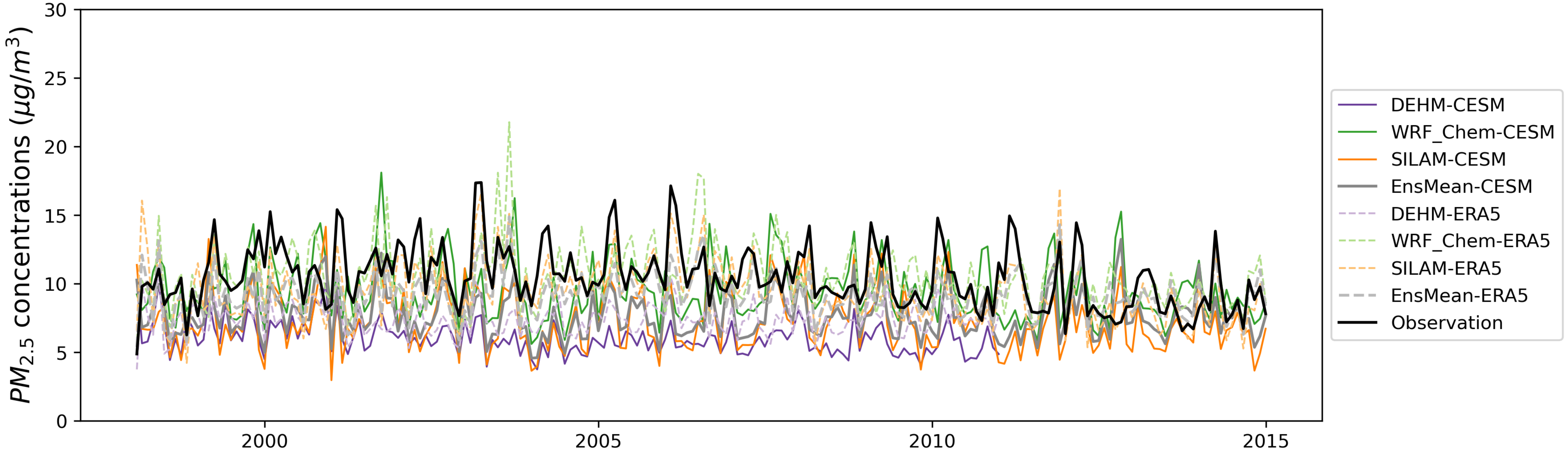
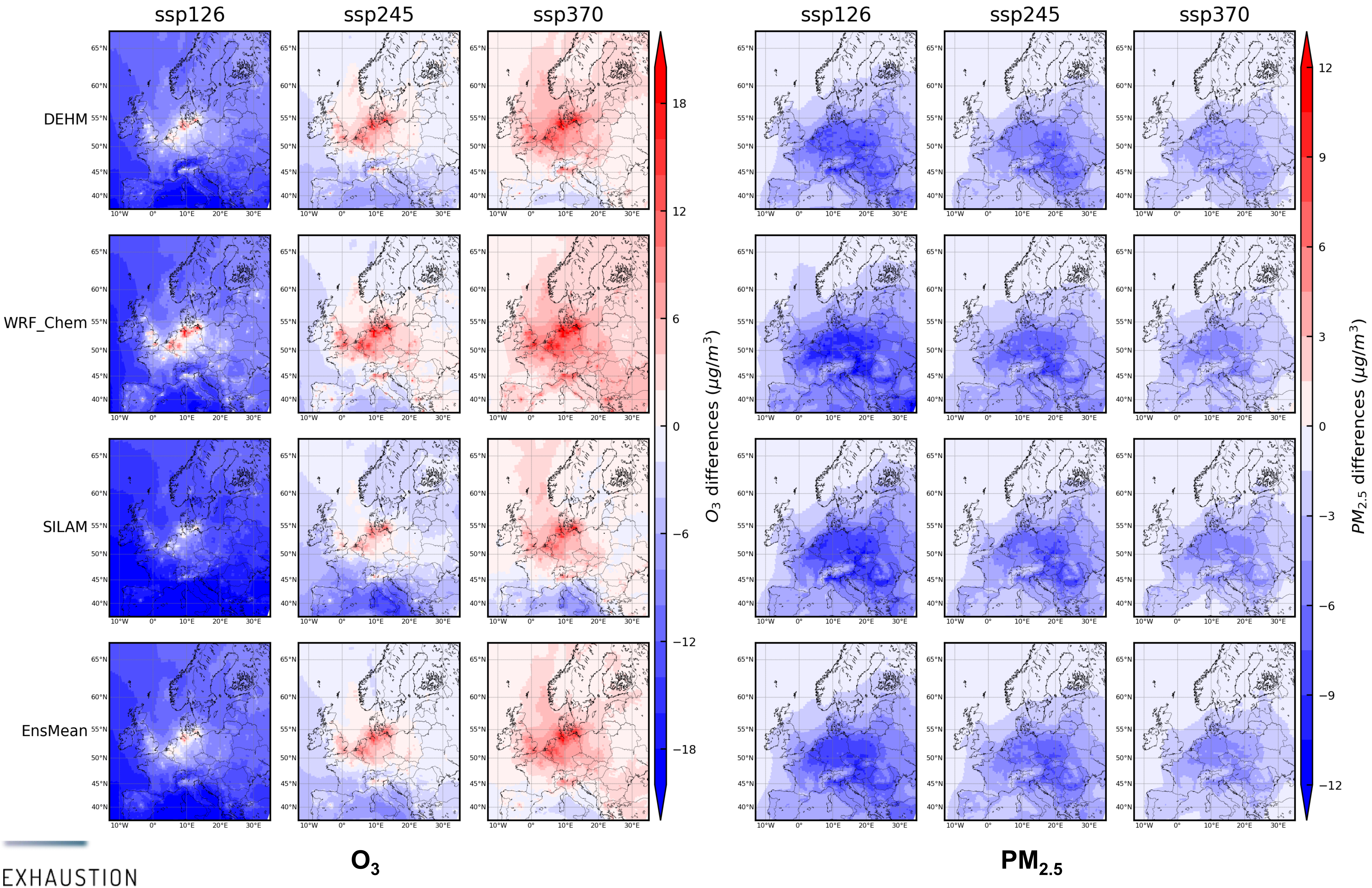
MODEL EVALUATION (Monthly means)





Simulation	Model	*r*	*NMB (%)*
ERA5-WRF	DEHM	0.91	-0
	SILAM	0.89	-6
	WRF-Chem	0.88	-8
	Ensemble	0.92	-5
CESM-WRF	DEHM	0.82	5
	SILAM	0.77	13
	WRF-Chem	0.74	1
	Ensemble	0.80	6

Simulation	Model	*r*	*NMB (%)*
ERA5-WRF	DEHM	0.62	-32
	SILAM	0.77	-11
	WRF-Chem	0.39	-2
	Ensemble	0.69	-15
CESM-WRF	DEHM	0.17	-44
	SILAM	0.16	-11
	WRF-Chem	0.08	-20
	Ensemble	0.14	-29



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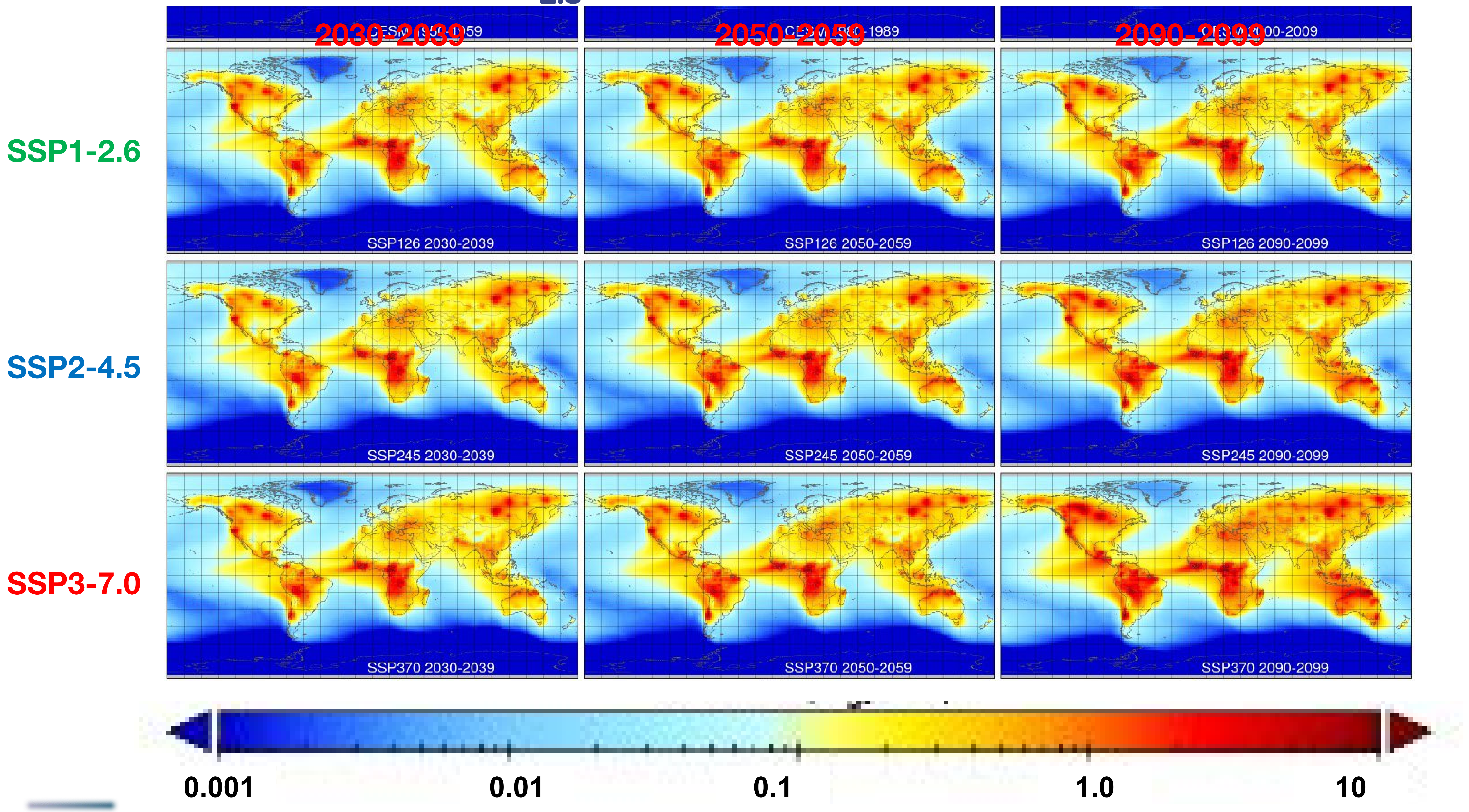
WILDFIRES – Surface $PM_{2.5}$



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STATISTICAL DOWNSCALING TOOL

Correlation coefficients between
observed and simulated surface temperatures

Capital	Correlation summer	Correlation winter
Amsterdam	0.79	0.79
Athens	0.87	0.66
Berlin	0.92	0.73
Bratislava	0.92	0.72
Brussels	0.91	0.80
Bucharest	0.89	0.80
Budapest	0.95	0.73
Copenhagen	0.90	0.85
Dublin	0.86	0.63
Helsinki	0.79	0.39
Lisbon	0.86	0.25
Ljubljana	0.96	0.22
London	0.93	0.58
Luxembourg	0.88	0.97
Madrid	0.81	0.52
Oslo	0.89	0.82
Paris	0.96	0.51
Prague	0.71	0.93
Riga	0.93	0.69
Rome	0.77	0.80
Sofia	0.92	0.85
Stockholm	0.30	0.64
Tallinn	0.93	0.80
Vienna	0.93	0.89
Vilnius	0.70	0.75
Warsaw	0.88	0.39
Zagreb	0.99	0.81

Correlation coefficients between
observed and simulated surface PM2.5

Capital	Correlation annual
Amsterdam	0.902
Athens	0.755
Berlin	0.966
Bratislava	0.976
Brussels	0.911
Budapest	0.986
Copenhagen	0.645
Dublin	0.923
Ljubljana	0.922
London	0.931
Lisbon	0.896
Helsinki	0.999
Madrid	0.794
Oslo	0.760
Prague	0.884
Riga	0.937
Rome	0.658
Paris	0.974
Stockholm	0.787
Sofia	0.998
Tallinn	0.988
Vienna	0.996
Vilnius	0.995
Warsaw	0.388
Zagreb	0.795

KEY RECOMMENDATIONS

- Ambitious mitigation of health and climate relevant air pollutants are needed to improve the health of European citizens.
- In addition to mitigation measures, effective adaptation strategies (e.g. nature-based solutions and heat action plans) are needed to alleviate the adverse impacts of heat waves and heat stress in Europe.

- More research is needed to improve climate and air pollution models as well as emission estimates that better consider European energy policies and population dynamics.
- More fine scale observations are needed (in-situ + satellites) at city scale